OPERATION AND RECENT DEVELOPMENTS

AT THE ESRF

REVOL Jean-Luc

Operation Group

Three-Way Meeting

APS, June 2-3, 2003

THE ESRF in 2003

Particles	*Electrons*	
Energy	6.03	GeV
Circumference	844	m
Multibunch Current	200	mA
Lifetime (uniform fill)	80	Hours
Horizontal emittance	4	nm.rad
Coupling	0.6	%
16 Bunch (Single) current	90 (16)	mA

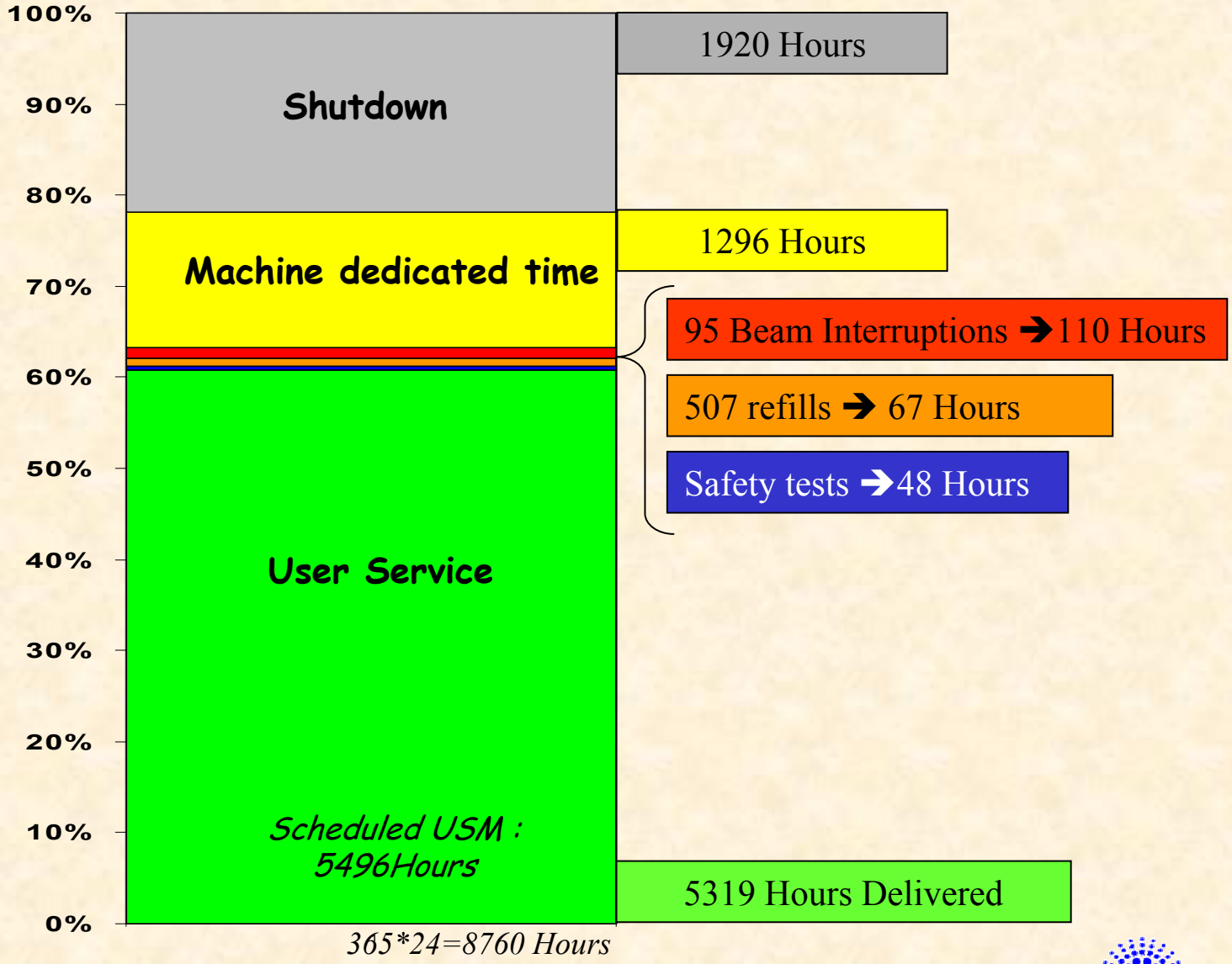
➔28 Straight Sections for Insertion Device beamlines equipped with:

64 in-air undulators segments

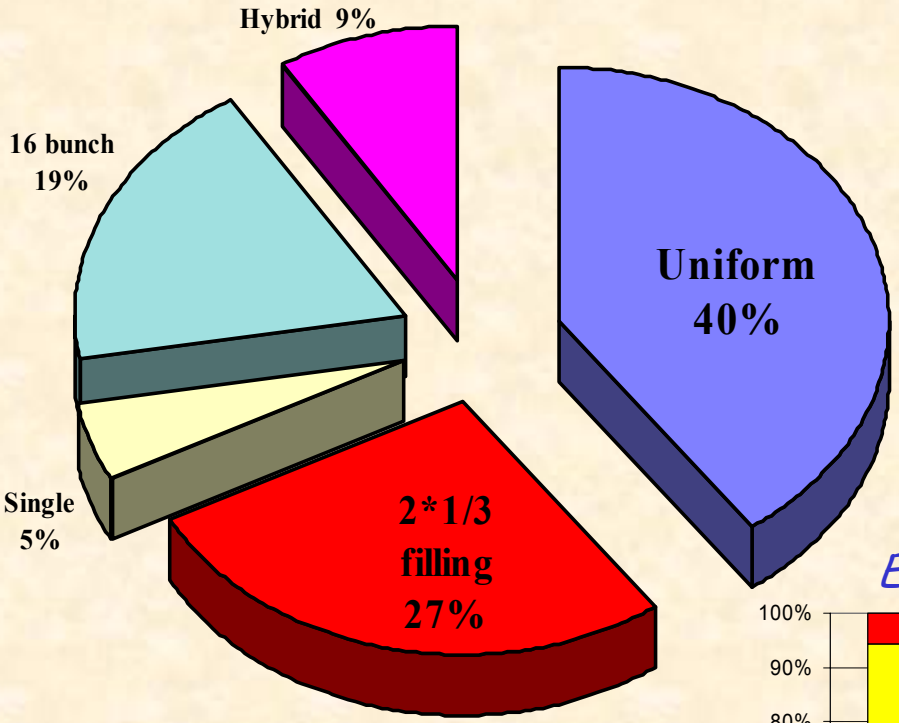
5 in-vacuum undulators

➔15 beamlines using the bending magnet radiation

Machine time over the year 2002

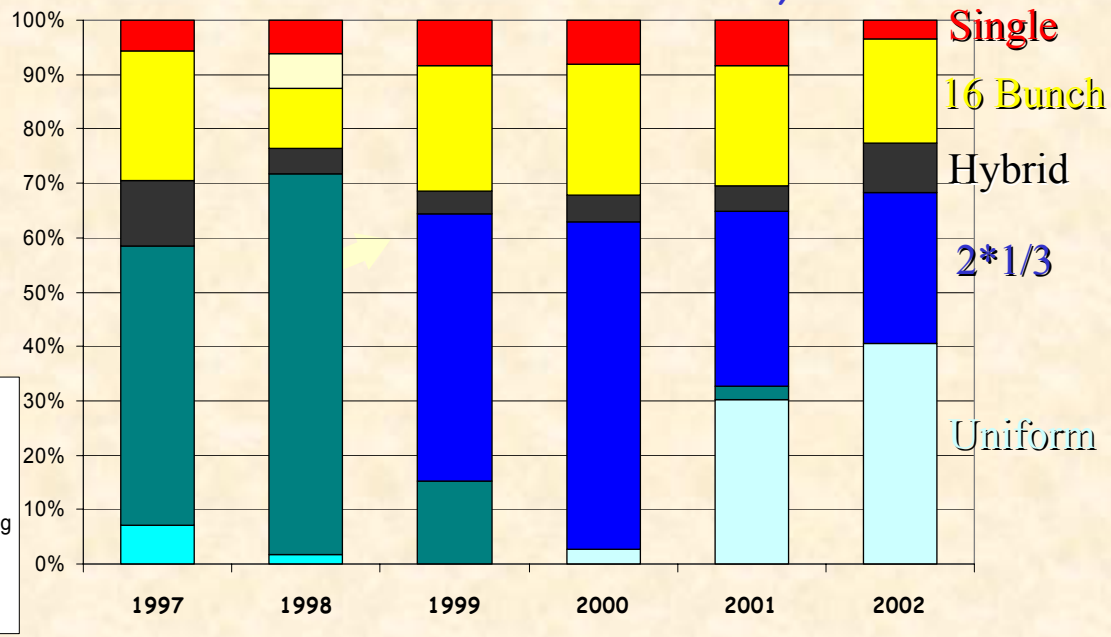


Filling mode



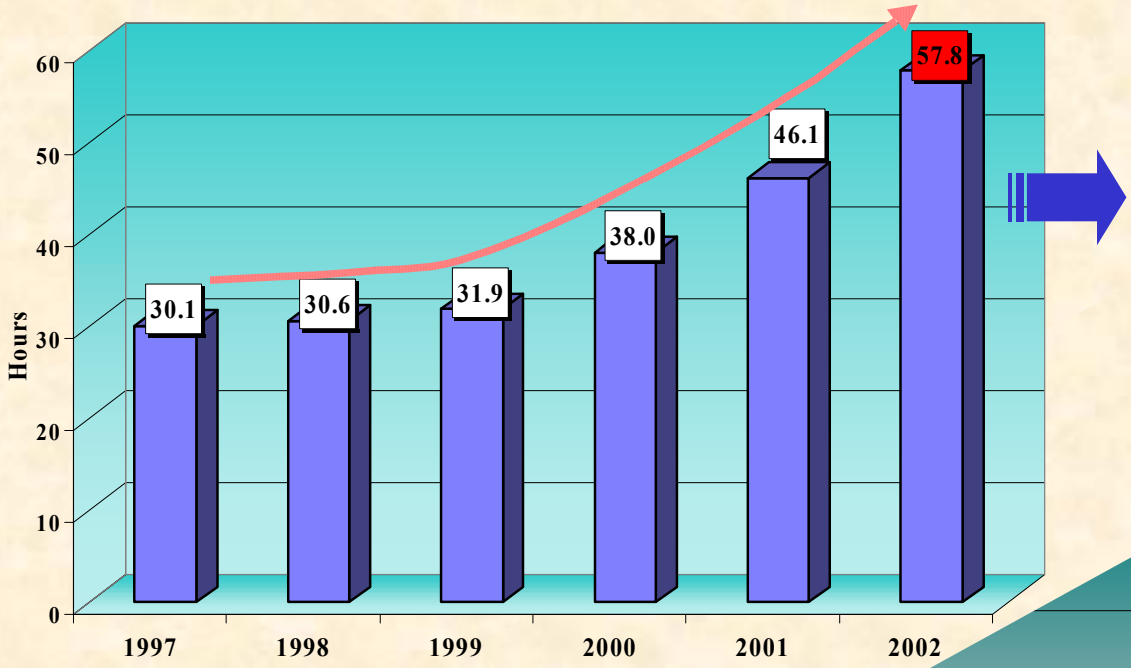
2002

Evolution of the modes over the years



Mode	Lifetime	Total Current
uniform	80 hours	200 mA
2*1/3	65 hours	200 mA
16 Bunch	12 hours	90 mA
single	6 hours	15 mA

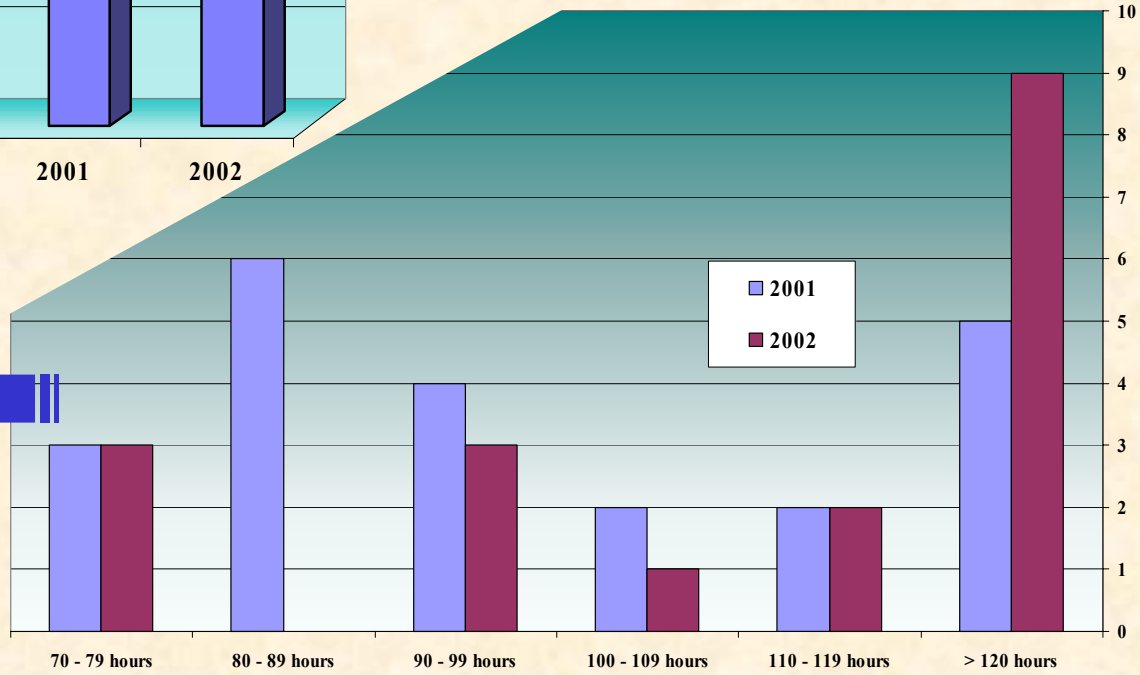
Highlights 2002

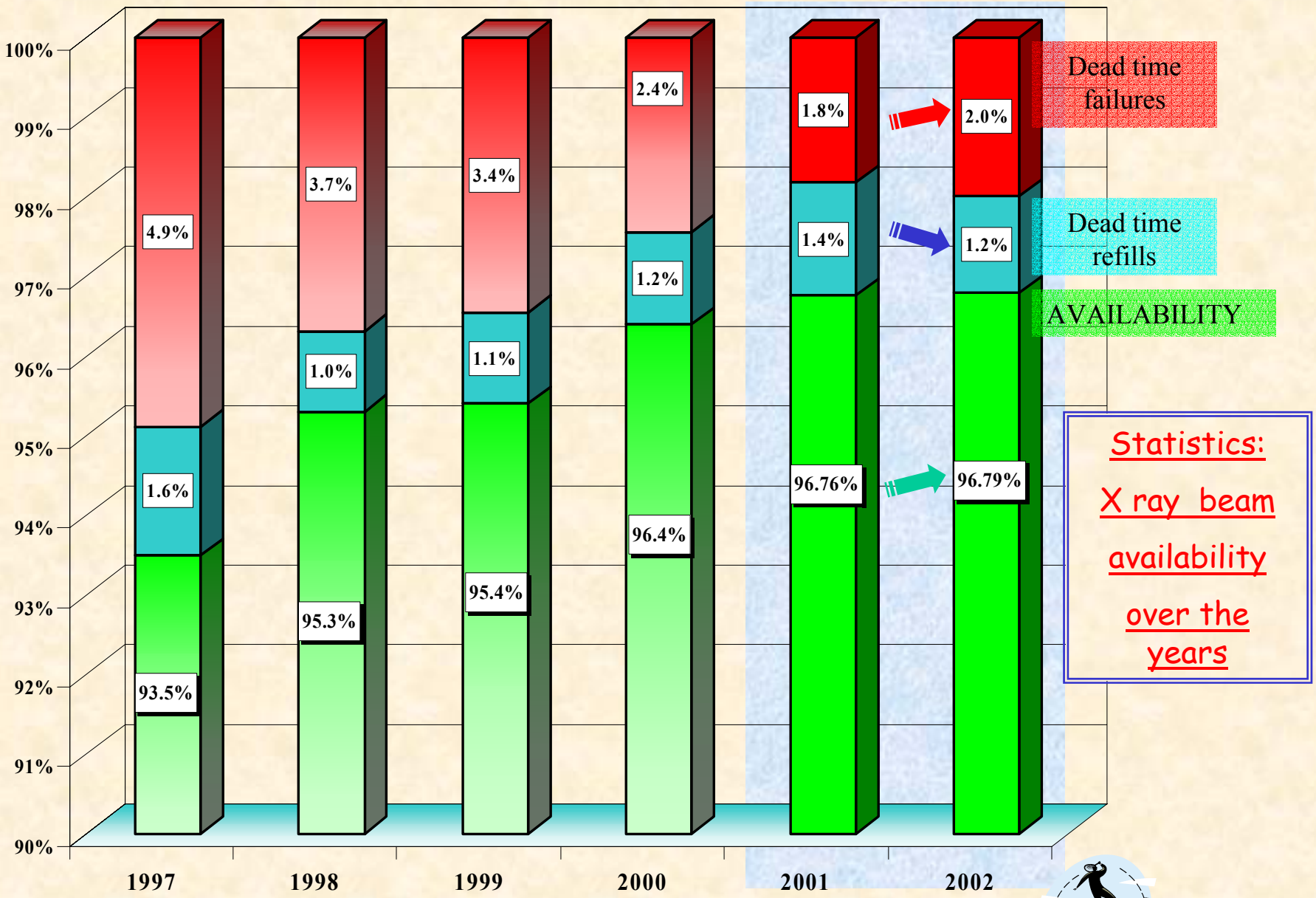


Confirmation of the increase in the mean time between failures

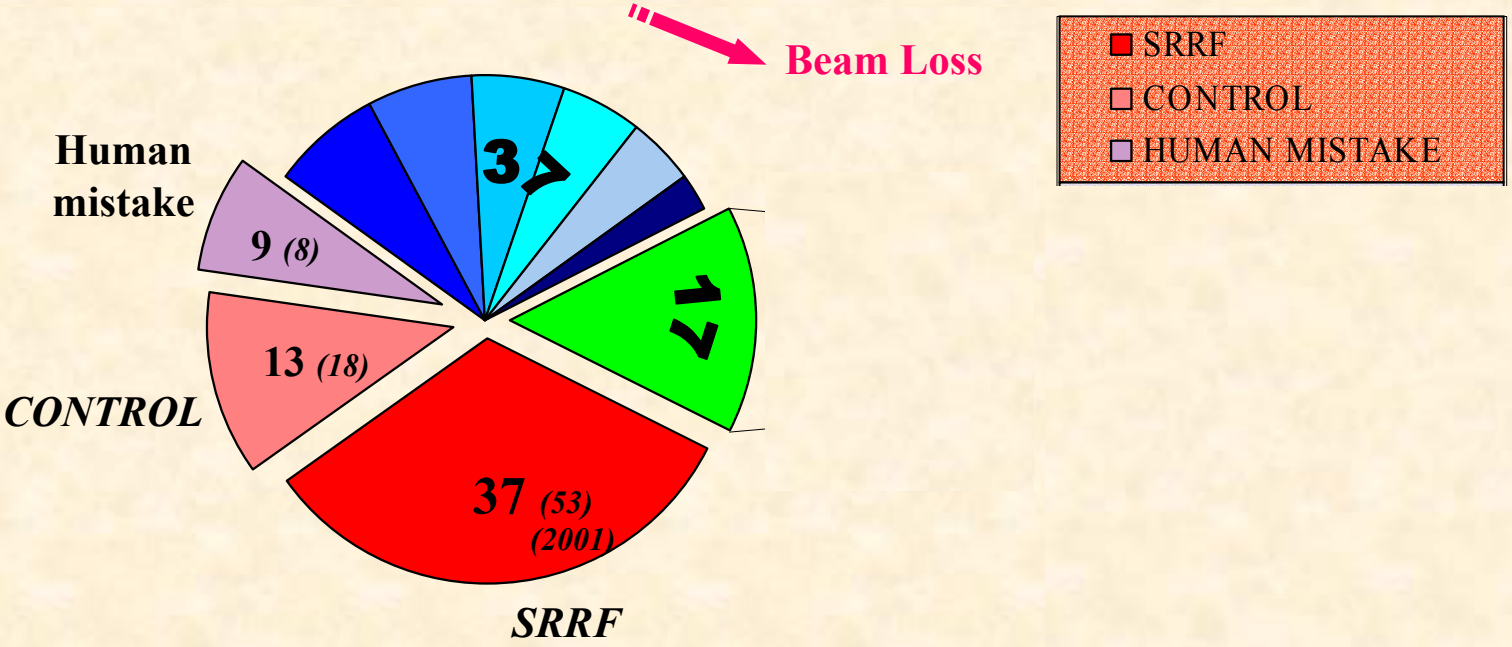
Average 2002 = 57.8 Hours

Increase in the number of delivery periods longer than 120 hours



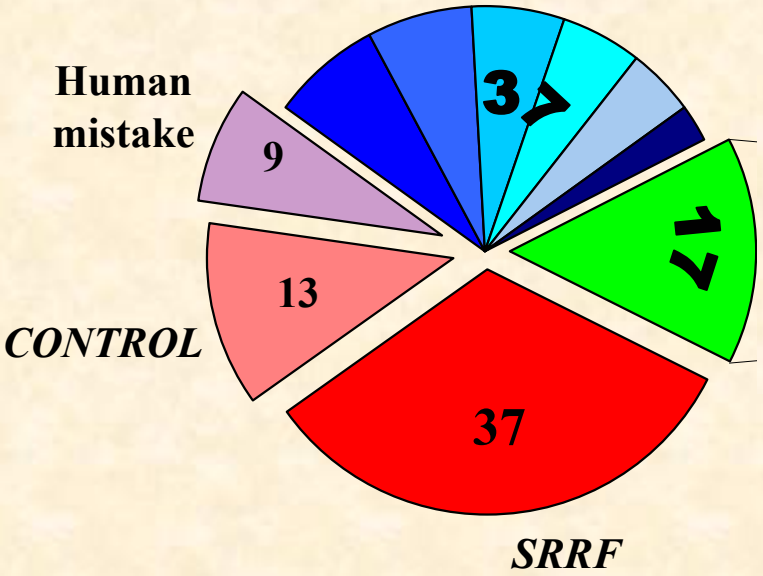

100%
99%
98%
97%
96%
95%
94%
93%
92%
91%
90%
1997
1998
1999
2000
2001
2002
4.9%
1.6%
93.5%
3.7%
1.0%
95.3%
3.4%
1.1%
95.4%
2.4%
1.2%
96.4%
1.8%
1.4%
96.76%
2.0%
1.2%
96.79%
Dead time failures
Dead time refills
AVAILABILITY
Statistics:
X ray beam availability over the years

Number of failures per piece of equipment in USM



Since 2001, special attention has been paid to the tracking and attribution of failures.

Number of failures per piece of equipment in USM



- SRRF
- CONTROL
- HUMAN MISTAKE

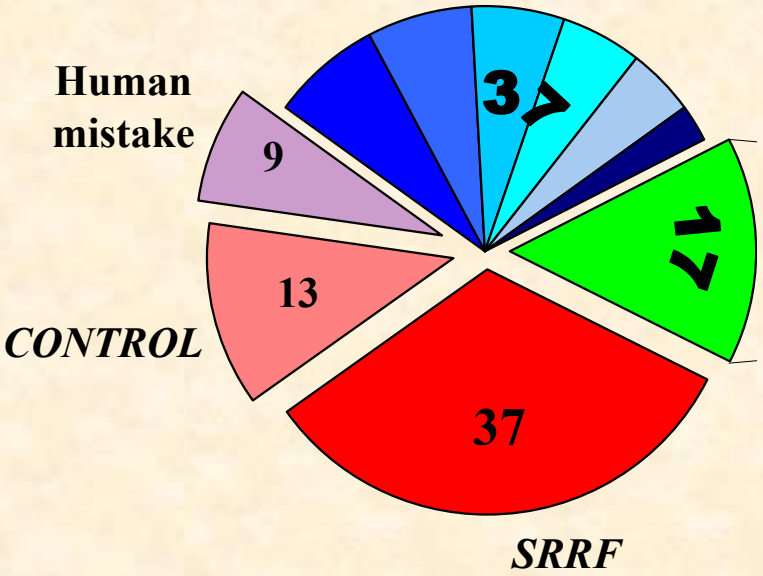
8 FE
8 UNIDENTIFIED
7 BEAM TUNING
6 SRMAG
5 INFRASTRUCTURE
3 SRPS

17 Other

Since 2001, special attention has been paid to the tracking and attribution of failures.

Total Time Lost = 110 Hours

Number of failures per piece of equipment in USM



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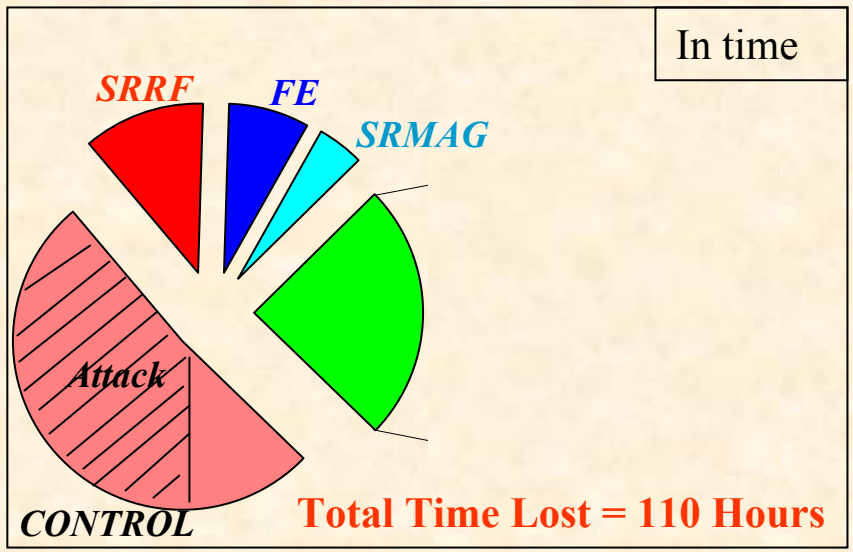
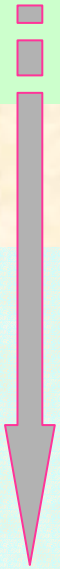


Control is **now** a key system for the operation and performance of our machine

Evolution to low gap

11 mm beam
stay clear

Stainless steel
5 m length *(11 mm inner aperture)*



Low gap

Lower Resistivity

Stainless steel /Copper coated
NEG Coated
5 m length (8 mm inner aperture)
5

Aluminum
NEG Coated
5 m length (8 mm inner aperture)
1

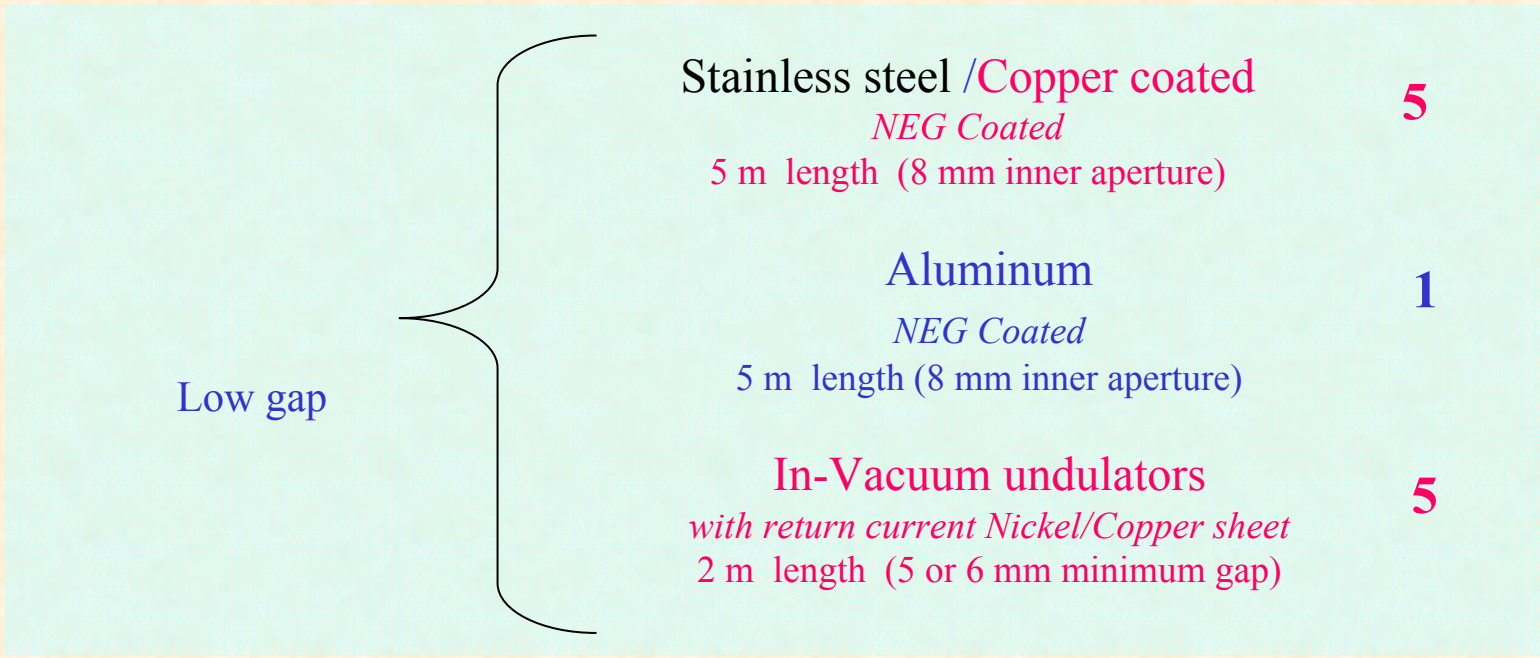
In-Vacuum undulators
with return current Nickel/Copper sheet
2 m length (5 or 6 mm minimum gap)
5

Two evolutions should be considered:

1) Machine impedance (resistive and geometric)

associated with beam current instability thresholds

2) Incoherent quadrupole tune shift generated by
the vertical/horizontal asymmetry (as a function of the current)
existing for both resistive and geometric wakes.



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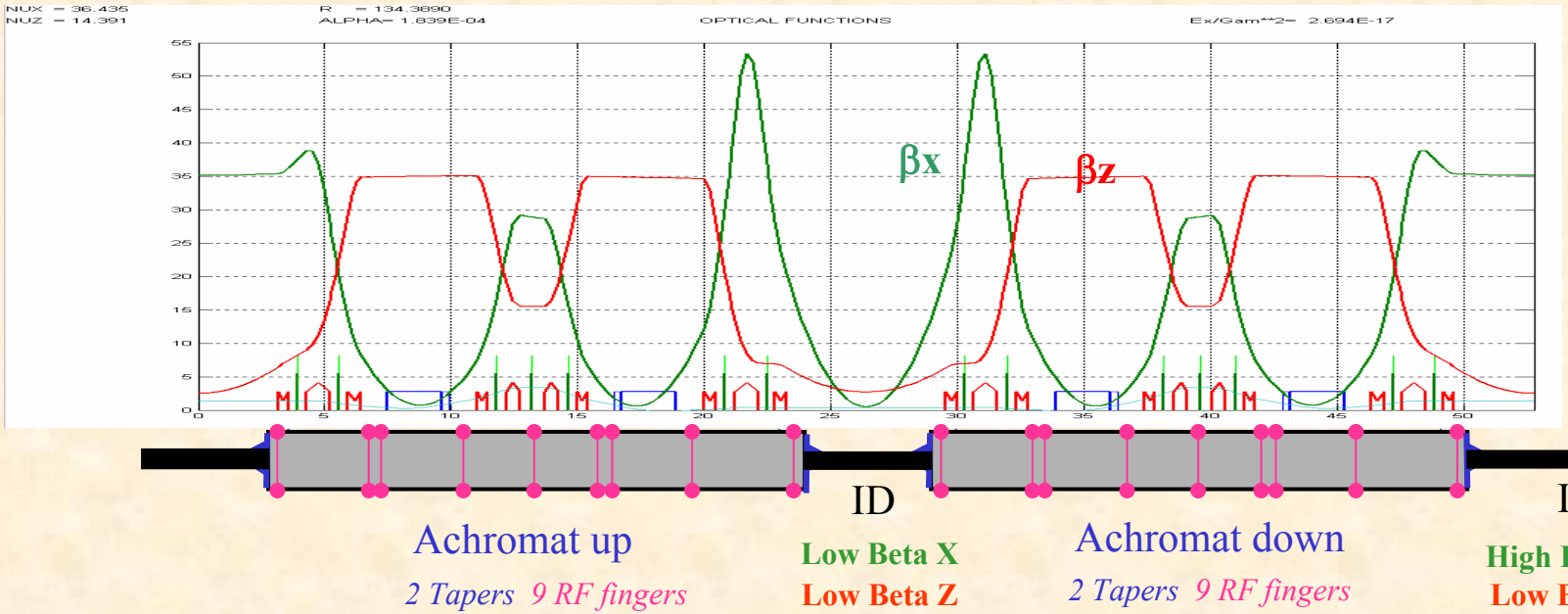


All these effects should be weighted with the corresponding β functions.

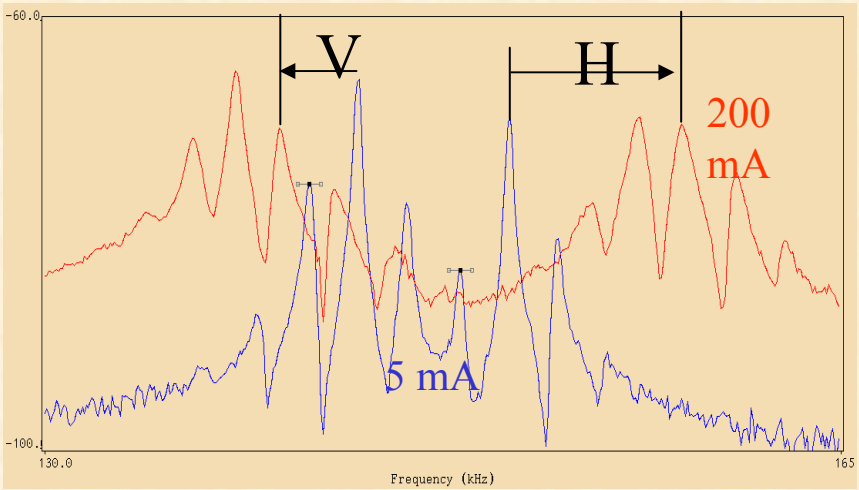
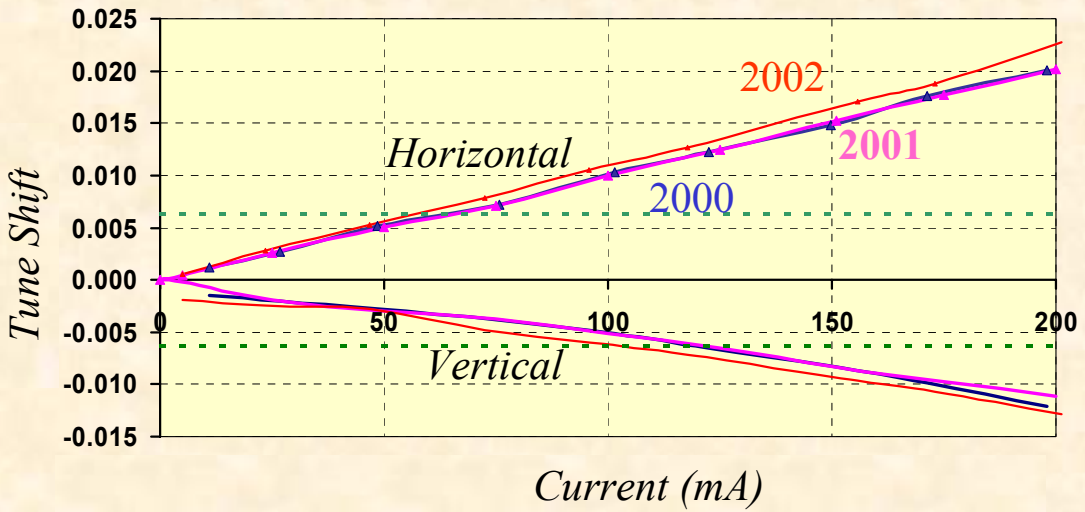


Illustration of the Incoherent quadrupolar detuning

observed in multibunch between 0 and 200 mA



Consequence on the beam performance over the last 3 years

Multibunch:

Detuning: *No significant evolution.*

Threshold H or V: No macroscopic evolution.

Single Bunch zero chromaticity

Vertical: *No significant evolution.*
Horizontal: Large decrease of the threshold.

Single Bunch, 16 Bunch & Hybrid: operational chromaticity

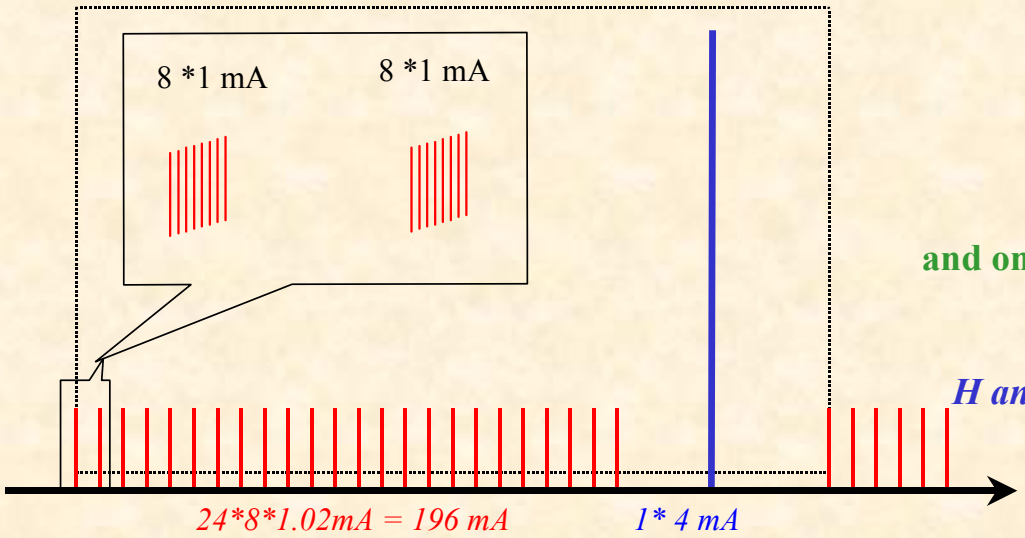
Vertical: *No significant evolution.*
Horizontal: Decrease of the threshold.
Increase of the incoherent tune shift.
Dependence of the threshold on the tune and on the horizontal emittance !!

No evolution in the vertical plane despite a strong reduction of the vertical aperture

However, strong effects on the horizontal single bunch beam dynamics.

The operational current in single bunch was recently reduced to 14.5 mA (instead of 20 mA)
And this mode will be replaced by 4 bunches at 10 mA for the next runs.

New Hybrid Mode



A new hybrid mode has been developed

24 groups of 8 bunches (1mA each)

and one single bunch in the middle of the gap (4mA)

Lifetime = 26 Hours at 200 mA

H and V emittances are comparable to multibunch

Largest difficulty:

Achievement of the purity contrast between the main bunches and the adjacent unfilled bunches (10^{-9} in routine operation).

Difficulties to apply the cleaning procedure

Transverse vertical excitation at the betatron frequency of the low populated (unfilled) bunches, (applied in the storage ring).

Intensity Ramping to 250 mA

First test in 2001 stopped due to radiation level exceeding the authorized level outside the shielding at some points.
➔ campaign of systematic shielding reinforcement.

Tests resumed in April 2003:

➔Acceptable radiation level

➔ No abnormal pressure and temperature increase on critical components (crotch absorber, RF windows,…)

Stable beam in 1/3 and 2/3 filling

BUT

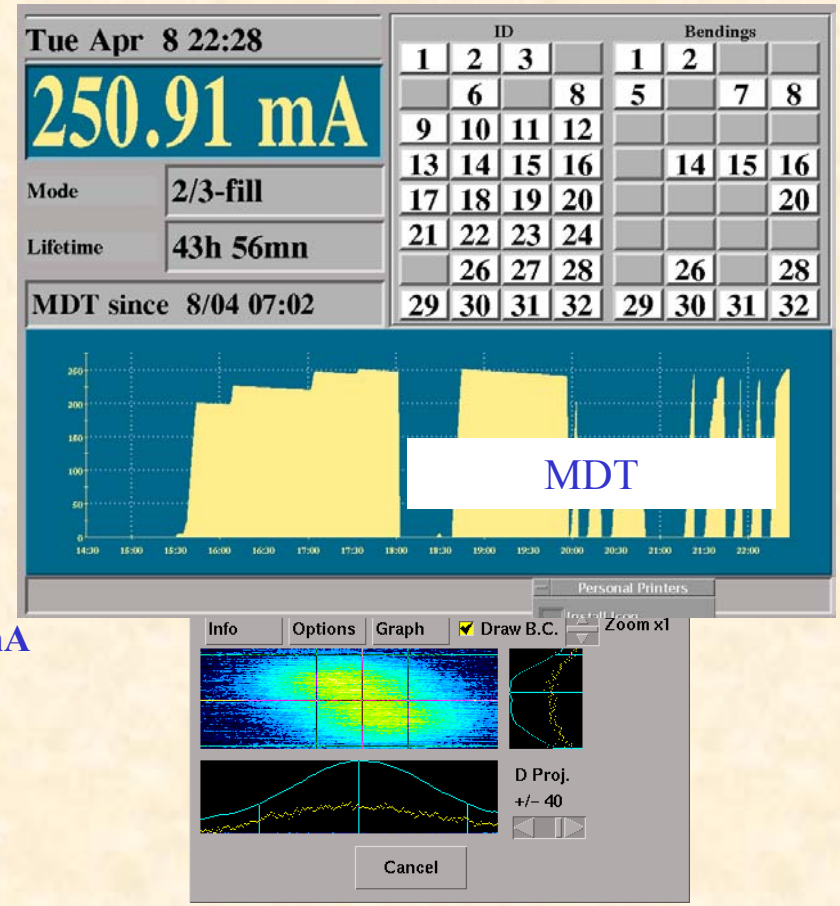
Evidence of a transverse HOM in uniform filling at 230 mA

Lifetime = 44 hours @250mA *compared to 60 hours at 200 mA (in2/3)*

Next: Still to find a RF working point in Uniform.

Still a few upgrade to do on the front end.

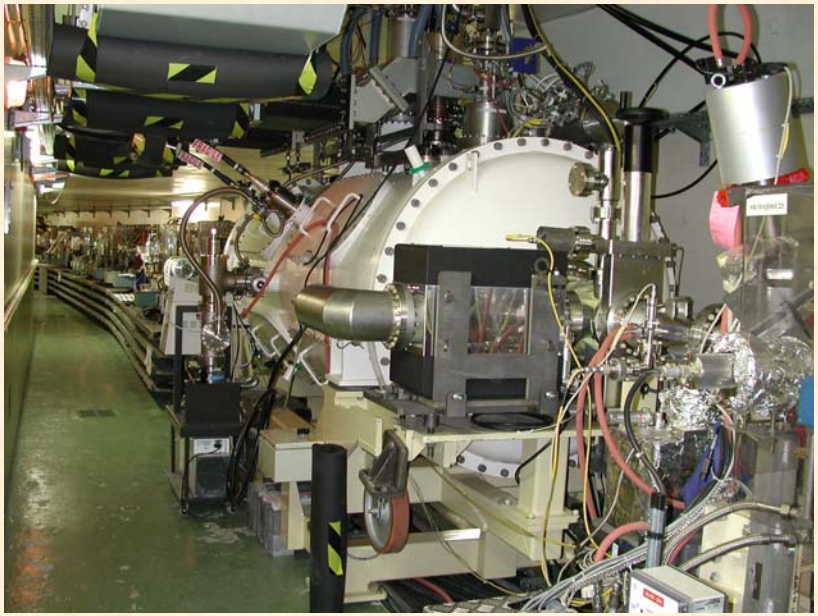
Users should be ready to take it.



First observation of a transverse HOM at the ESRF!!!

Test of the SOLEIL superconducting cavity

Prototype Cryo-module housing two superconducting
352 MHz strongly HOM-damped cavities installed on the ESRF storage ring for one year.



During user service mode:

Maintained detuned at room temperature in passive regime

Only 3 beam trips over one year!!!

During Machine Dedicated Time:

Four tests in the accelerating regime at 4.5K with liquid helium cooling from Dewars.

Conditioning up to 4 MV

170 mA stored with 3MV from the Soleil cavity (360 kW beam power)

Successful prototype test
Contribution to the finalization of the design
Valuable option for a possible future upgrade at the ESRF

Injection with Front End Open

In Operation from the 5 February 2003

Objectives: **Reduction of the thermal load variation during injection on beamline components**

Safety Aspects:

1) Control of the dose rates outside optics hutches

➔*Installation of 43 radiation monitors preventing injection with the front end open if the dose exceeds the dose limit for non exposed workers: 2 μSv/ 4h.*

2) Preventing the injection of the electron beam to a beam line

➔ Impossible if there is stored beam in SR

➔ Integration of a dedicated current monitor into the personal safety system (5mA minimum stored beam)

3) All effort put into getting a high as possible lifetime and tuning the injection is certainly beneficial to reduce the doses rates.

Radiation monitor close to the hutch of a beamline

Not a single front end closed during injection due to excessive dose !!

More information in P. Berkvens' presentation

Injection with Front End Open

Operational Aspects:

1) Synchronization of data acquisition:

➔ *Implementation of a software counter to inform the beamlines of the injection schedule.*

2) Maintain the magnetic gap of undulators and wigglers unchanged during injection

But, in order to prevent demagnetization of permanent magnet material exposed to high energy electrons,

➔ Closer control of losses during injection.

➔ Use of more resistant material (Sm2Co17 instead of NdFeB) for in-vacuum IDs.

➔ Limitation of the minimum gap to 8mm (instead of 6mm) for all in-vacuum IDs during injection.

⇛ **Minimum gap at injection will be reduced further after a detailed study on the machine beamline (Long term)**

3) Maintain the injection rate thanks to the naturally long lifetime

➔ Typically once every 12 hours in multibunch.

4) Reduction of the injection duration *(consequence)*

5) But now…. All beam losses occurring during injection should be considered as a failure in the statistics !!

Injection with Front End Open

Feedback from users:

The benefit is strongly dependent on the beamlines and experiments

➔ **But feedback was Extremely Positive from ALL beamlines !!!**

For the most sensitive beamlines:

In multibunch:

- ➔ Thermal variation induced by the refilling (from 160 to 200 mA twice per day) has almost disappeared
- ➔ No realignment after injection
- ➔ Low injection frequency, thanks to the naturally long lifetime (as opposed to frequent topping-up) to avoid injection perturbation.
- ➔ Some of beamlines are using beam during injection to perform long scans.

⇒ **Increase of the beam availability for most of the beamlines**

In 16 Bunch, Hybrid and Single bunch the situation is less favorable:

- ➔ Reduced lifetime imposes more frequent injection to reduce the current variation
- ➔ Cleaning process in the SR prevents from using the beam during injection for a few minutes

⇒ **Cleaning in the booster is being studied**

Presentation on behalf of

P. Berkvens, J.C. Biasci, P. Elleaume, P. Duru, L. Farvacque, T. Günzel, L. Hardy, J. Jacob, R. Kersevan, G. Naylor, Y. Papaphilippou, E. Plouviez, A. Ropert, K. Scheidt, V. Serriere.

… and many other colleagues from

Machine Division, Technical Services and Computing Services.

Injection with front ends open at the ESRF

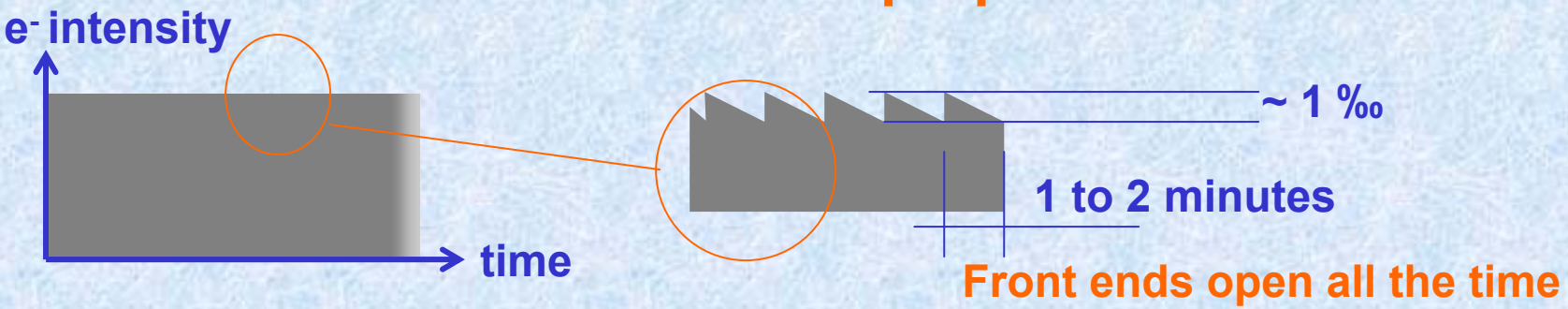
P. Berkvens
European Synchrotron Radiation Facility

1. Injection with front ends open
2. Safety assessment
3. Interlocked radiation monitoring system

Summary of the talk prepared by P. Berkvens

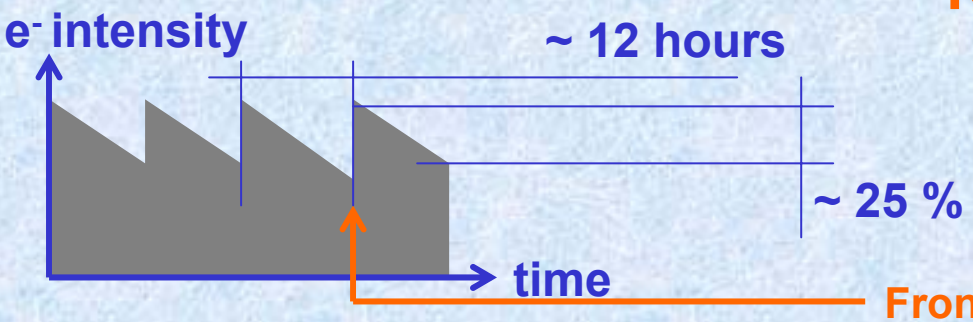
Injection with FE open at the ESRF *P. Berkvens*

continuous top-up



experiment	?	+: perfect thermal stability +: constant e- stability ?: detector gating
machine operation	-	•operation cost: electricity bill, spare parts (klystron) •reliability of injector
safety	-	•radiation hazard •interlocked radiation monitors + PSS upgrade

Injection with FE open at the ESRF *P. Berkvens*



Non-continuous top-up with front ends open

experiment	+	+: good thermal stability 0: detector gating → solution: trigger signal or close shutter end optics hutch
machine operation	0	
safety	-	•radiation hazard •interlocked radiation monitors + PSS upgrade

Injection with FE open at the ESRF *P. Berkvens*

1. Radiation hazard: injected electron beam into beamline

   Hypothesis: top-up with front ends open only allowed if beam already stored in storage ring

   ➔ safety assessment: SR beam optics

   ➔ develop dedicated beam current monitors and integrate into PSS

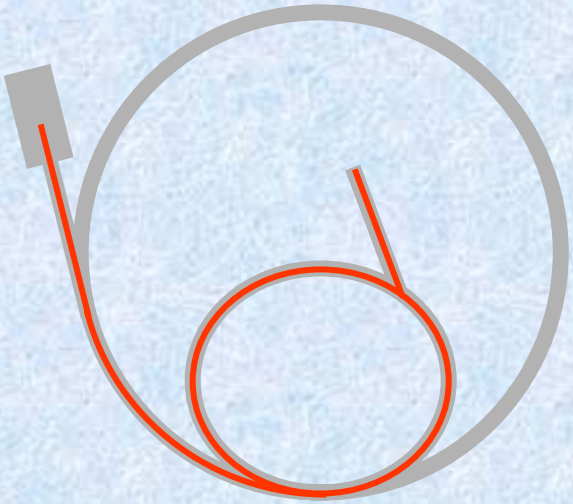
2. Radiation hazard: injection losses in straight section

   Study of the maximum losses during injection

   ➔ dedicated radiation monitors integrated into PSS

Injection with FE open at the ESRF *P. Berkvens*

1. **Radiation hazard:** injected electron beam into beamline



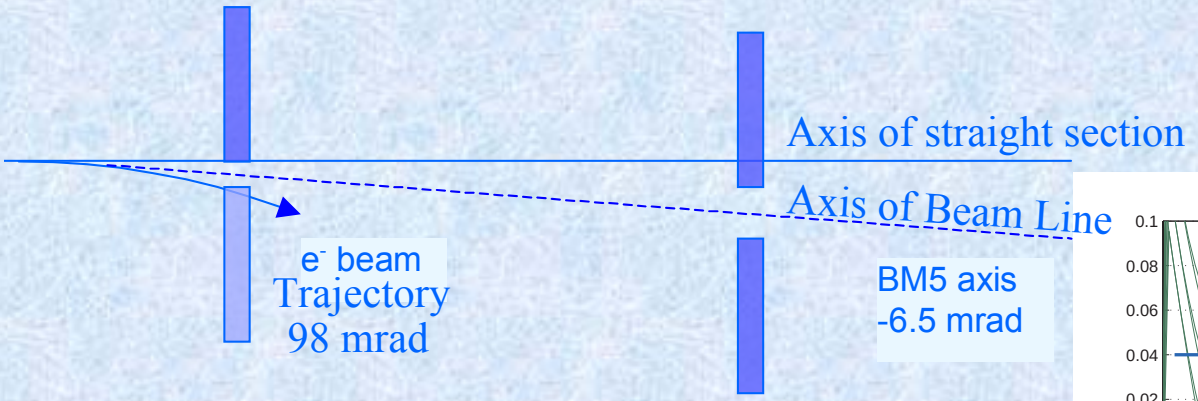
5 mA, 1 μs pulse from booster
behind side wall: 100 μSv per pulse
behind back wall: > 1 mSv per pulse

Injection with FE open at the ESRF *P. Berkvens*

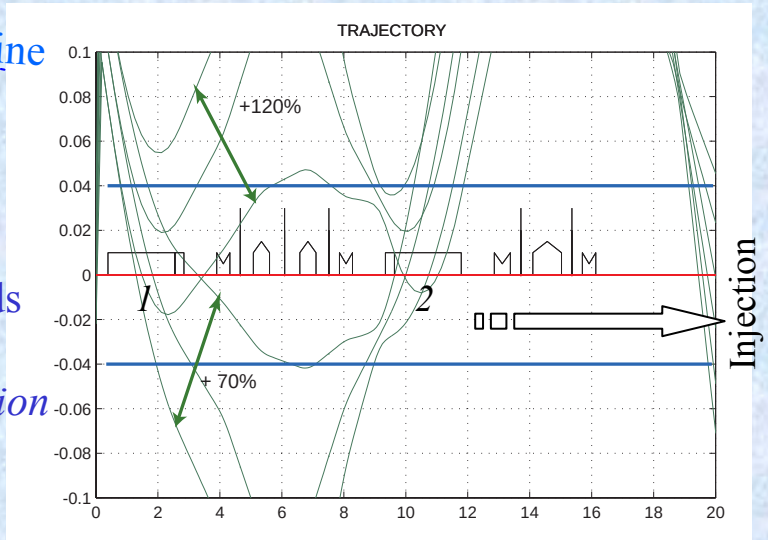
Acceptance of the beamline defined by:

Crotch
[-12, 0] mrad

Slit
[-9.5, -3.5] mrad



Theoretical study
(L. Farvacque)
→Impossible to inject into
1st beamline (BM05)



The acceptance of the beamline is propagated backwards to the injection section,

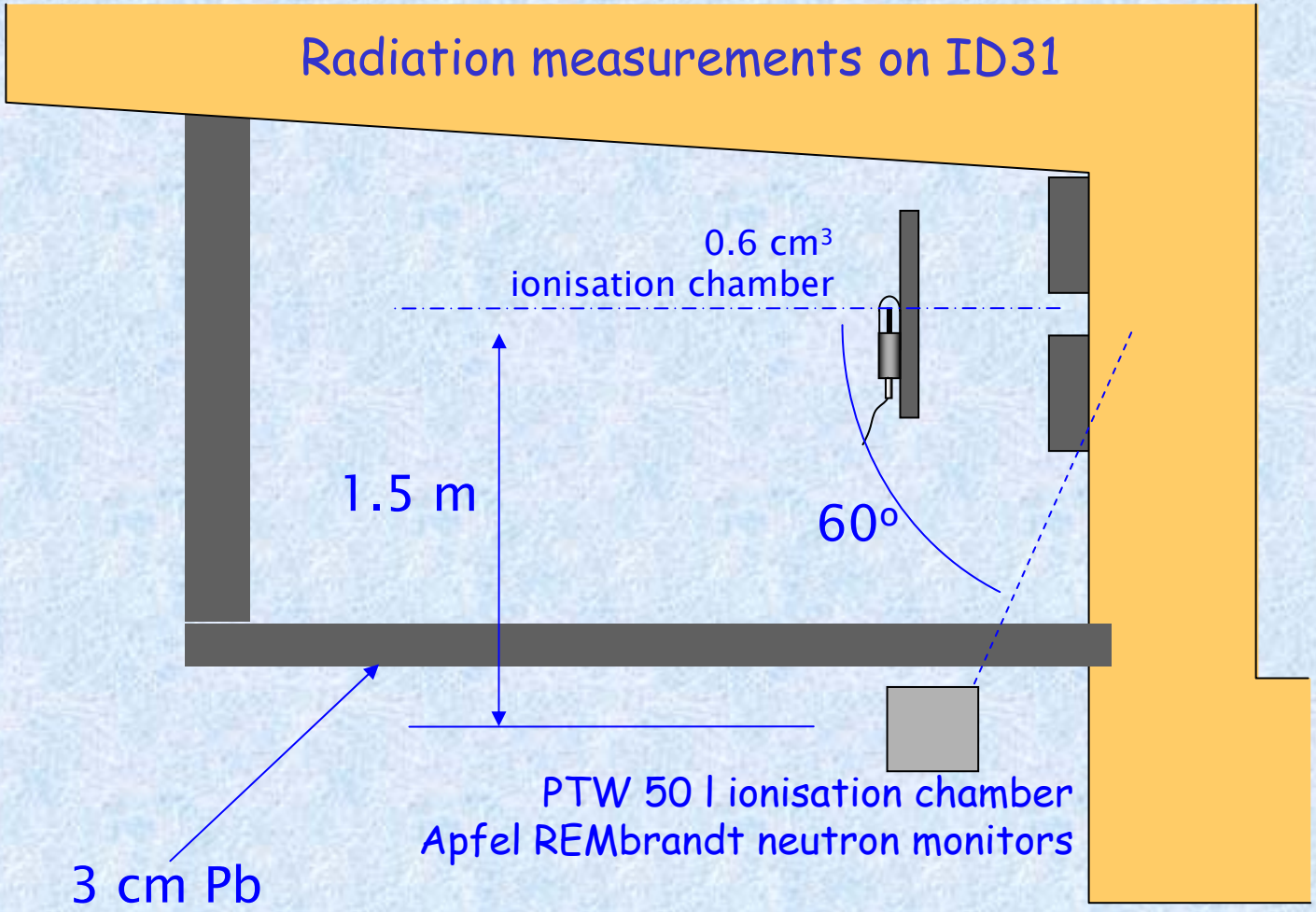
* *with the hypothesis that there is the condition for a stored beam*
* *with various energy of the injected beam.*

With the condition which allow to go back through the first achromat, the beam is then lost on the second dipole, well before reaching the injection zone.

Injection with FE open at the ESRF *P. Berkvens*

2. **Radiation hazard**: injection losses in straight section

➔ Study of the maximum losses during injection (2001)



Injection with FE open at the ESRF *P. Berkvens*

Radiation tests on 26/06/01 and 19/08/01: conditions

- Radiation tests during injection with front end open have been carried out on:
  ID31 (low gap chamber) and BM25.

- Photon and neutron doses outside the optics hutch were integrated during full 200 mA fills.

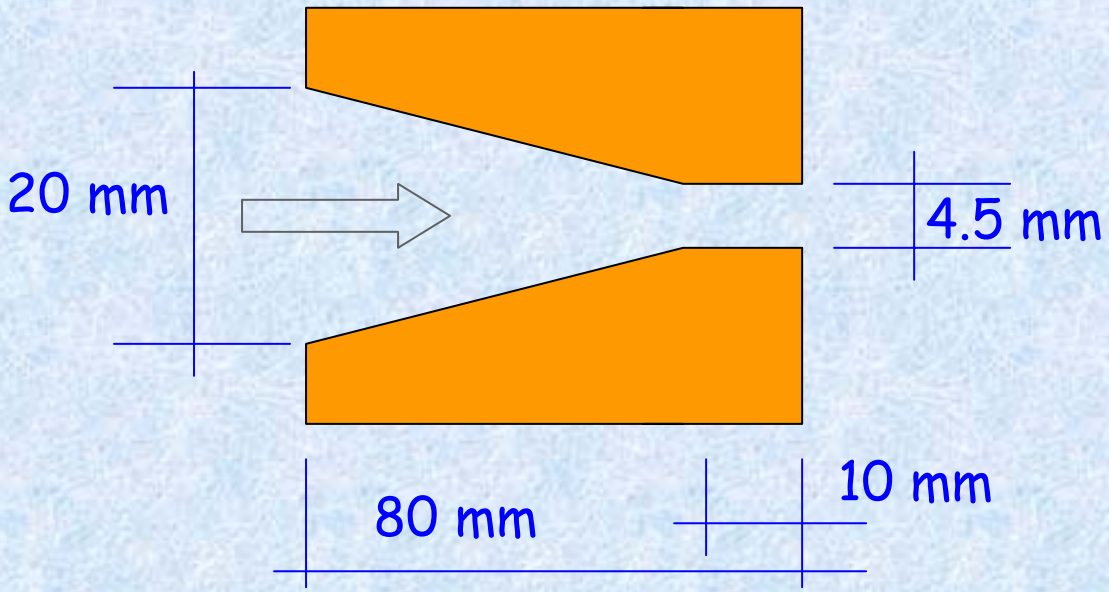
- Doses were measured for different storage ring conditions:
  1. *Nominal conditions*
  2. *Cell 6 scraper further closed: injection efficiency decreases but local losses in cell 31 decrease*
  3. *All scrapers fully open: injection efficiency increases but local losses in cell 31 increase*
  4. *All scrapers fully open and coupling correction off: local losses in cell 31 increase drastically*

- During these measurements the overall injection efficiency was about 50 %.

- The normal 4.5 mm copper aperture in the ID31 front end:
  on 25/06/01 not installed,
  on 19/08/01 installed.

Injection with FE open at the ESRF *P. Berkvens*

cylindrical front end aperture



✓ installed on the undulator front end

Injection with FE open at the ESRF *P. Berkvens*

Conclusion on the feasibility of injection with front ends open

recall:

➔ *Decree Euatom/9629 for non exposed worker*

1 mSv.y^{-1} → 0.5 μSv.h^{-1} ➔ ∫dose over 4 hours < 2 μSv

➔ Normal operation ➔ *50 mA injected every 12 hours*

Dose Integrated for **one** 50 mA top

***nominal SR conditions*:**

without f.e. aperture: 0.48 μSv

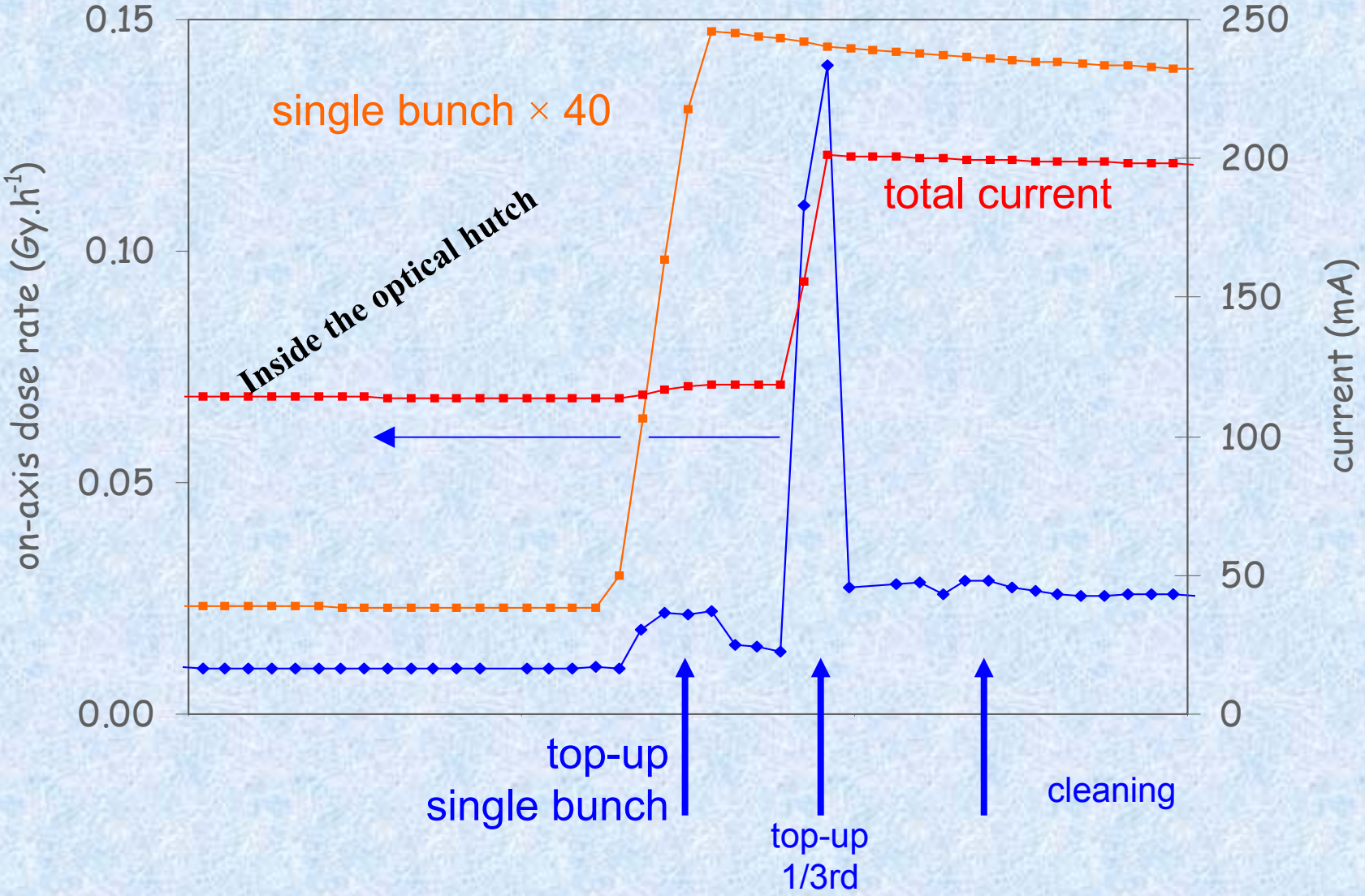
with f.e. aperture: 0.03 μSv ⟸ Nominal operating condition

worst SR conditions:

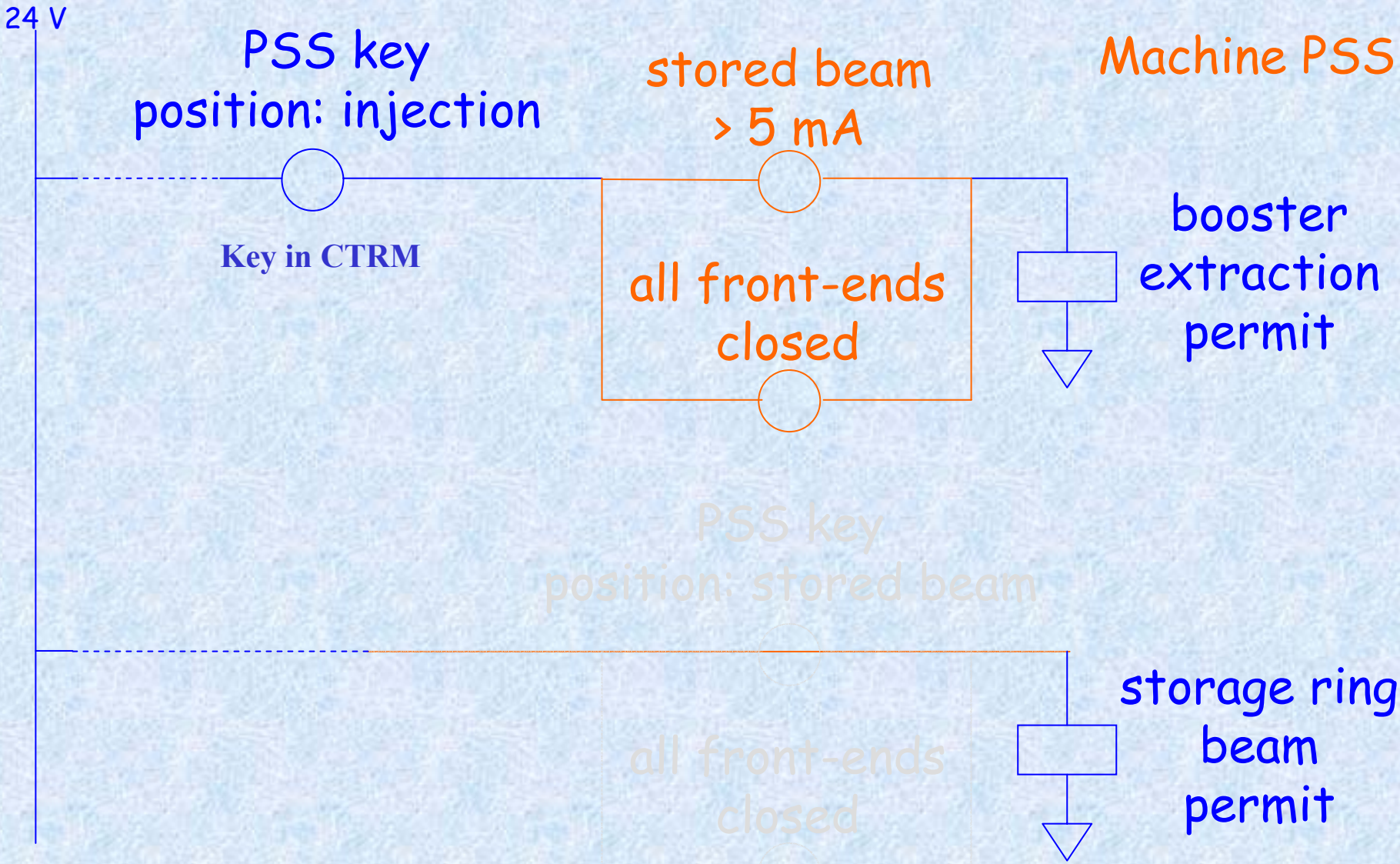
without f.e. aperture: **14 μSv**

with f.e. aperture: 0.64 μSv

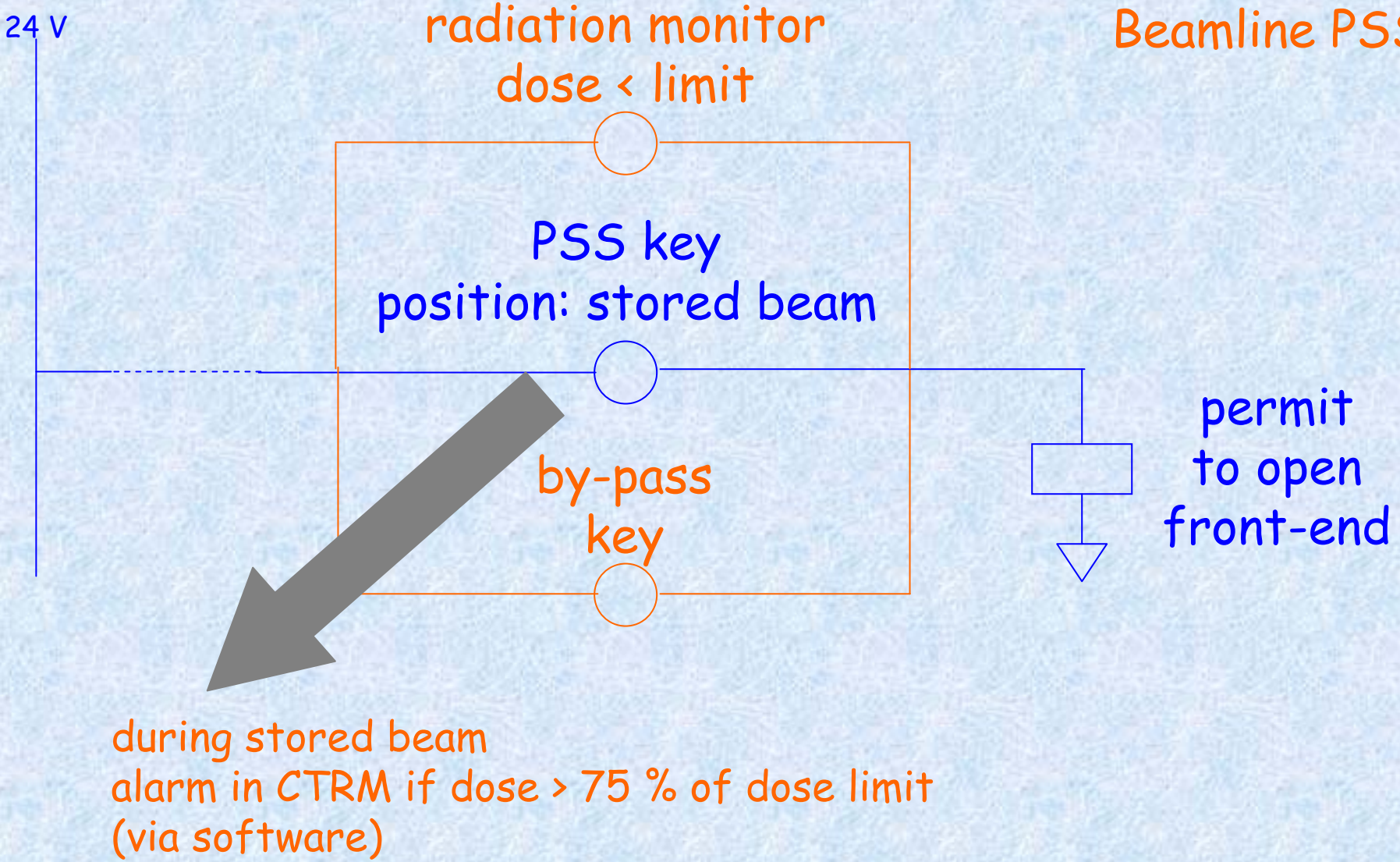
Hybrid mode: single bunch + 1/3rd filling
on-axis bremsstrahlung measurements on ID6



Injection with FE open at the ESRF *P. Berkvens*

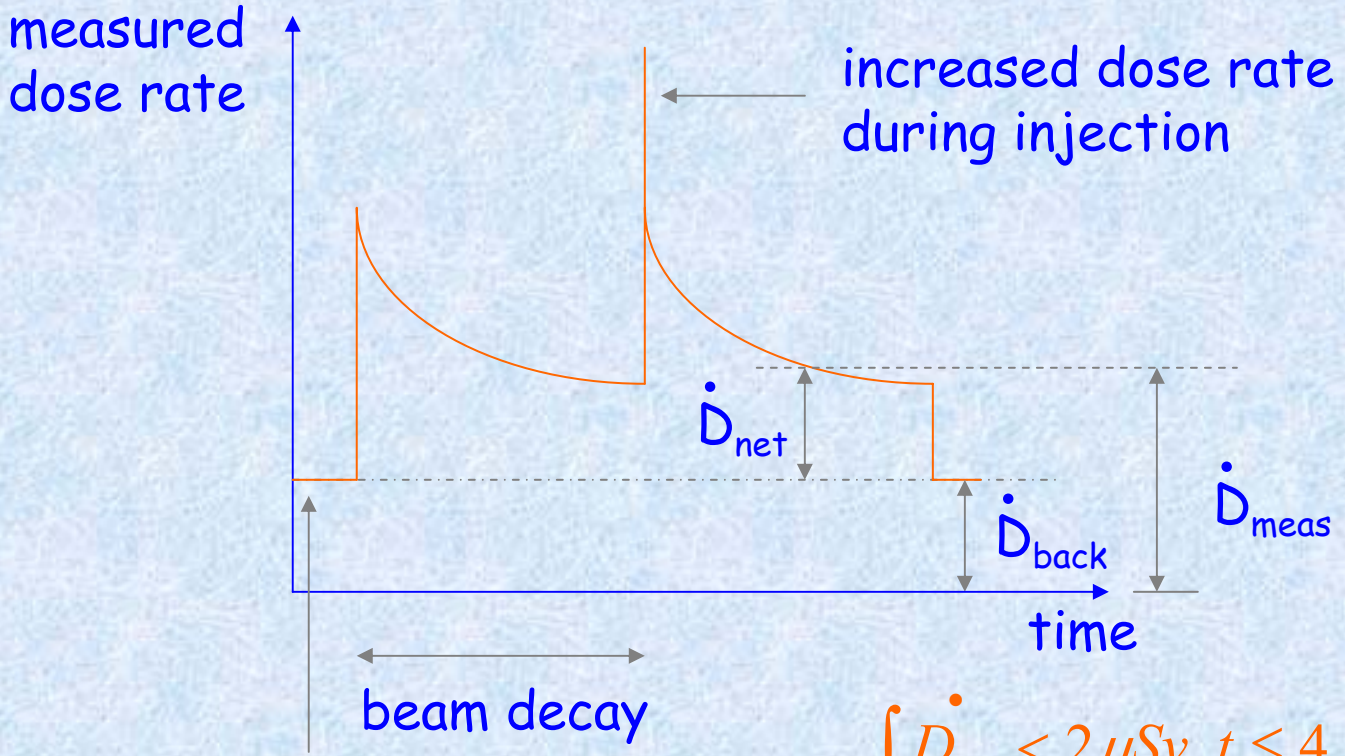


Injection with FE open at the ESRF *P. Berkvens*



Injection with FE open at the ESRF *P. Berkvens*

Injection with FE open at the ESRF *P. Berkvens*

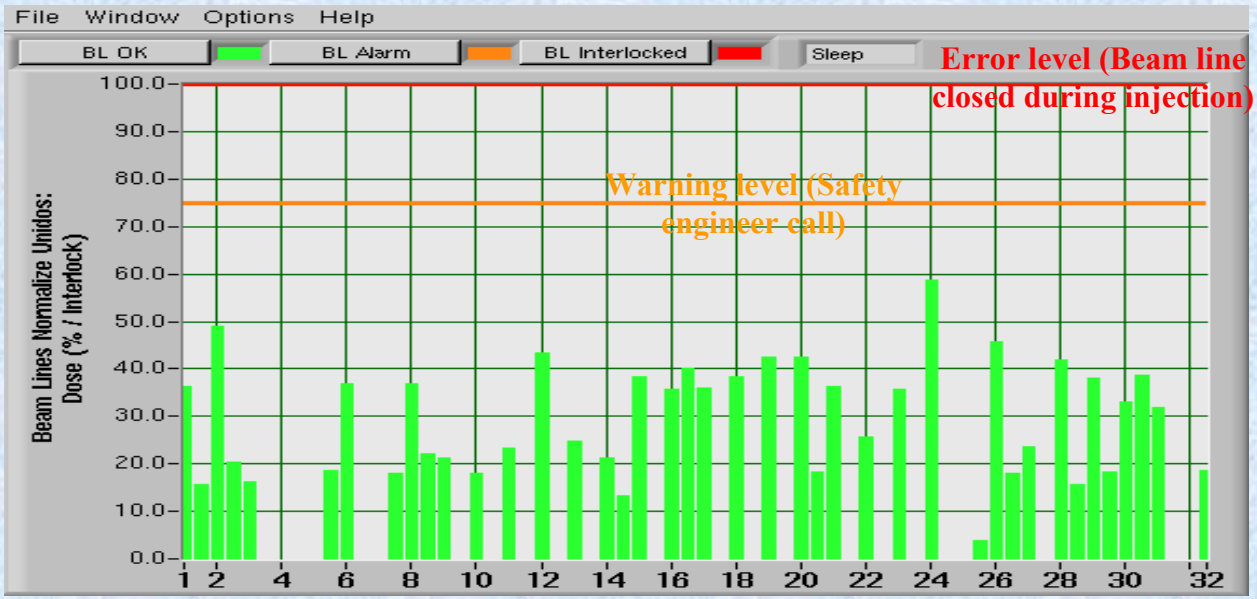


$$\int_t \dot{D}_{tot} < 2\,\mu Sv,\ t \le 4\ hours$$

neutrons ≈ 2 × photons

$$\int_t \dot{D}_{meas}\,dt < \frac{2 + 8 \times \dot{D}_{back}}{3}\ \mu Sv$$

Injection with FE open at the ESRF *P. Berkvens*



All Beamlines

Typical accumulated dose of each monitor during 4 hours in Multibunch.

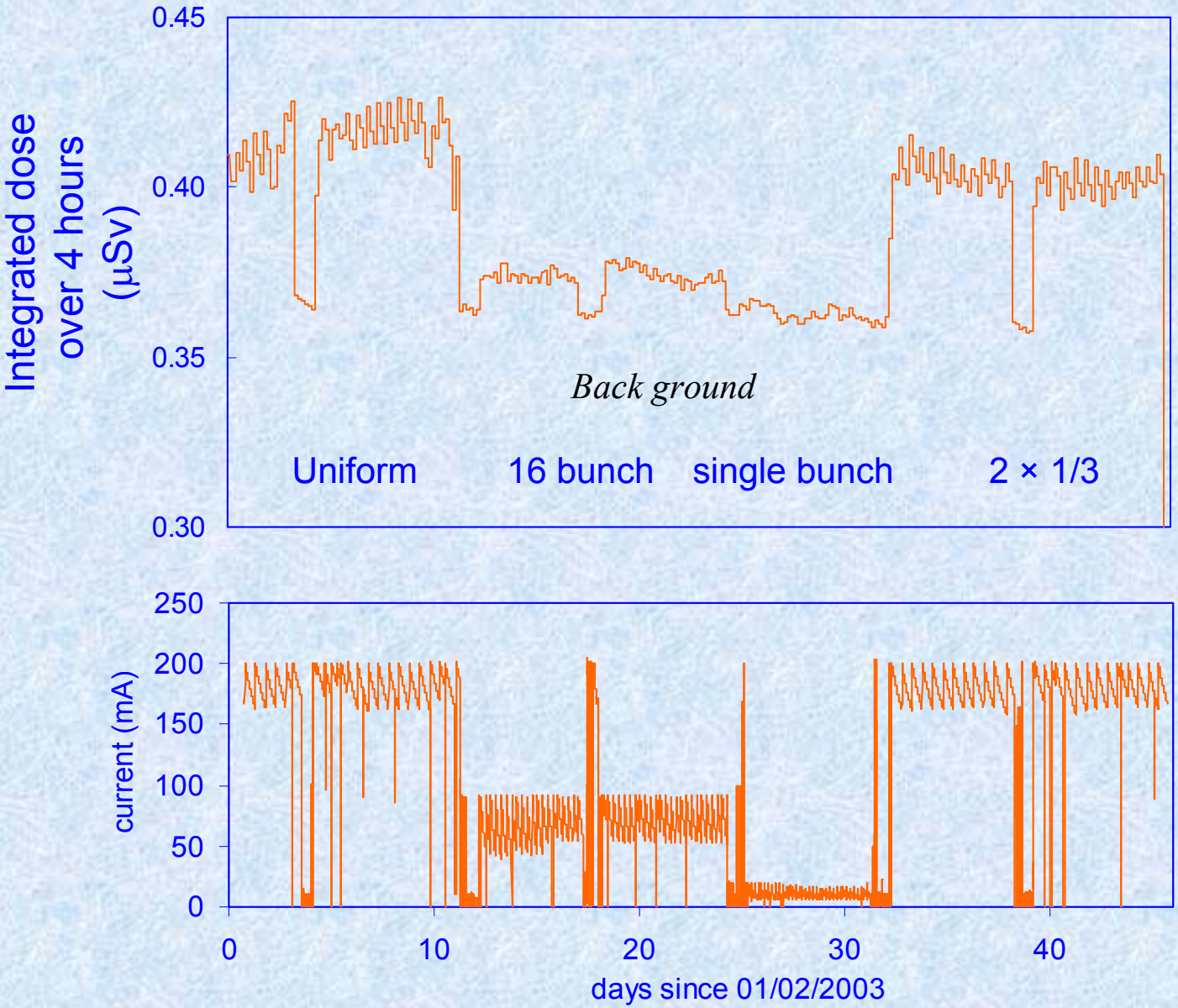
(Including: background, delivery and injection)

No beamline reached the warning level during the whole run

Injections have little influence on the accumulated dose.

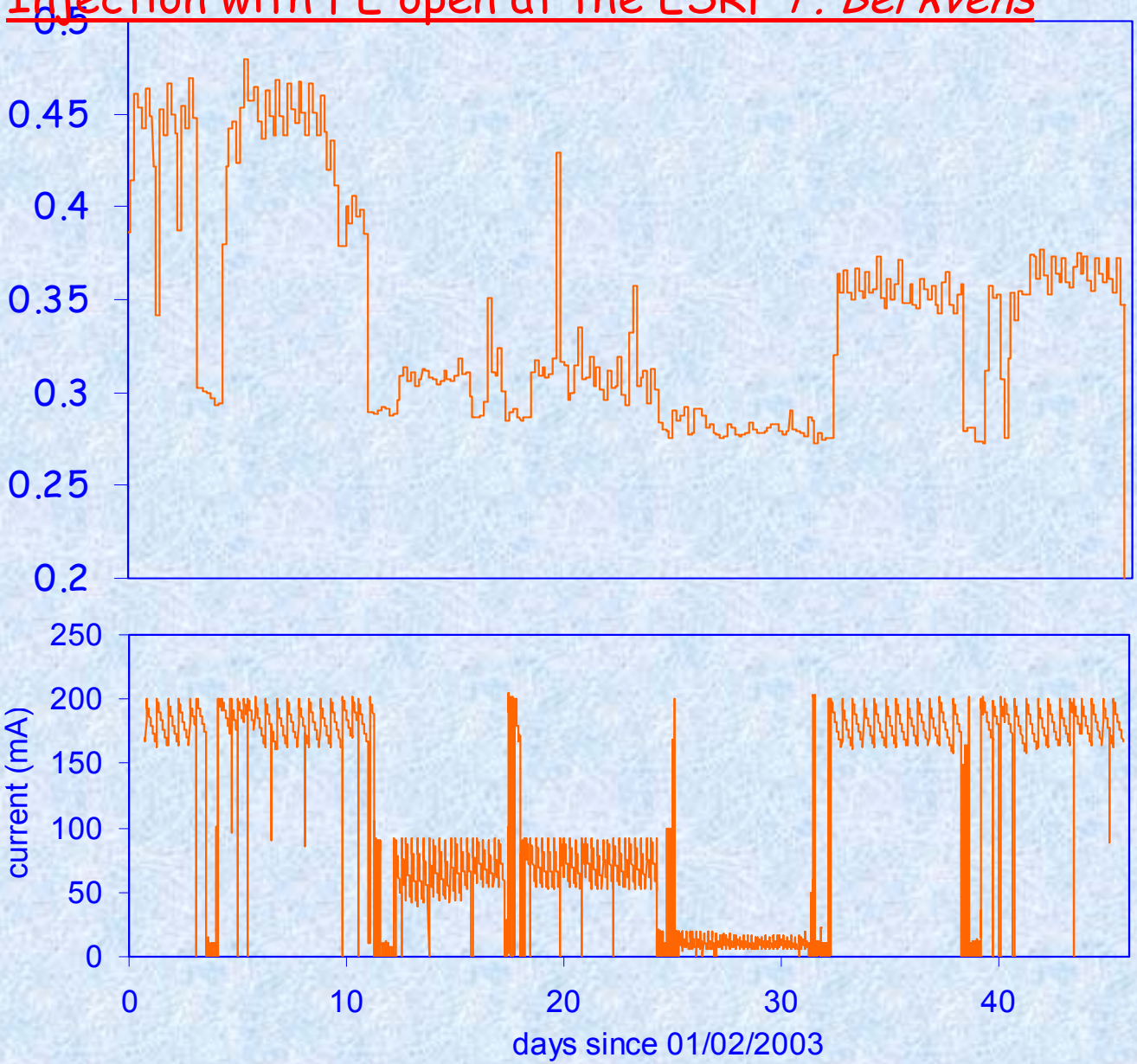
This is true for all operating modes !!

Injection with FE open at the ESRF *P. Berkvens*



Example:
ID14
Run 2003/1

Injection with FE open at the ESRF *P. Berkvens*



Example:
ID21
Soft X-ray beamline
(no shutter end optics hutch)
Run 2003/1

Injection with FE open at the ESRF *P. Berkvens*

Example:
ID21
Soft X-ray beamline
(no shutter end optics hutch)
Run 2003/1